International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 7 (2018) pp. 5022-5025

Design and Parametric studies on Fractal element based Aperture type Curved Frequency Selective Surfaces (FSSs)

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Abstract

Semi cylindrical aperture type curved FSSs comprising of Koch snowflake and Vicsek fractal elements are designed. Their transmission characteristics are analyzed . Also parametric studies have been done on iteration numbers and types of fractal elements. Multiband as well as broadband(up to 19.45GHz) have been achieved for Bluetooth , Wi-Fi and satellite communication respectively.

INTRODUCTION

Frequency Selective Surface(FSS) is mainly an infinite structure with periodic arrangement of patch or aperture type element on the dielectric substrate or metallic sheet respectively [1]. But curved Frequency Selective Surface(FSS) is a finite structure with periodic elements[2]. Now a days ,fractal FSS becomes popular due to its excellent features. Multiband can be achieved by sierpinski fractal using several iterations[3-4]. Wide operating band has been obtained by using thin microwave absorber with single and double layer coating by using the fractal FSS. Fractal FSSs have been used to improve the bandwidth as well as absorption. Three types of fractal element based FSSs are analyzed such as sierpinski gasket, sierpinski carpet and minkowski loop. Among them sierpinski gasket fractal FSS shows better absorption characteristics .The bandwidth of fractal FSS (sierpinski gasket) and without fractal element based FSS are 4.2GHz and 3.1GHz respectively[5].An absorber with 3.1GHz bandwidth is achieved by sandwiching two sierpinski carpet layer FSSs for stealth application. The maximum absorption with a wide bandwidth has been achieved at lower thickness of 1.3mm with introducing double layer fractal seirpinski FSS rather than ordinary double layer absorber [6].T.K Wu demonstrates that FSS with minkowski fractal element exhibits better stable frequency responses at various incident angles and polarizations than the square loop and carpet fractal based FSS. At first resonant frequency i.e at 7 THz, the minkowski fractal based FSS presents good stability in frequency response up to 60 degree incident angle as well as TE and TM polarizations [7].A thin (2.1 mm) absorber with minkowski loop (level 2) based FSS exhibits broad bandwidth of 3 GHz with return loss -41dB at 10.30 GHz. But square loop and cross dipole based FSS presents maximum bandwidth of 1.8 GHz and 2.6 GHz respectively[8]. Broadband microwave absorber is formed by fractal element based FSS. Mainly minkowski fractal FSS acts as a good absorber[9].In this paper[10] effects of substrate thickness, resistors in the lossy absorber, angular variation were investigated on the bandwidth and absorption level. At the resistor value of 196 ohm for the outer loop, broad band as well as lower reflection have been achieved. A simple novel FSS absorber loaded with resistor based double fractal square loop element presents 133% bandwidth with better reduction of reflectivity. Reflectivity of FSS absorber depends on the thickness of the spacer. Low reflectivity has been obtained with the substrate thickness of 16 mm by compromising Bandwidth .So bandwidth was increased by decreasing the thickness of substrate. A square loop fractal stop band FSS covers both GSM 900 and GSM1800 bands with good attenuation. For TE polarization , minimum bandwidth has been achieved at 45 deg and 60 deg incident angles. For TM polarization the bandwidth is decreased due to increase of incident angle with good attenuation ranging between 18-38 dB and 22-36 dB for both GSM 900 and GSM1800 bands respectively[11].A symmetric FSS consisting of cross shaped spiral patch with second iteration of H shaped fractal element in clockwise rotation exhibits stable characteristics response with variation of incident angle from 0 deg to 80deg for both TE and TM polarization[12].

In this paper, different aperture type curved fractal FSSs are designed up to level 2 iteration to investigate various parameters of their transmission responses.

DESIGN OF FSSs:

Various types of planar fractal FSS are designed and analyzed in microwave engineering field for many applications. But design of curved fractal FSSs are very advanced in microwave field. In this paper, aperture type curved fractal FSSs are designed and analyzed. Their characteristic responses are studied for different iterations. For ignoring the complexity of design , up to two fractal levels are considered. Aperture type curved FSSs are designed with Koch snowflake and Vicsek fractal element up to level 2 iterations. The unit Koch snowflake and Vicsek fractal element with iterations are presented in fig 1 and fig 5 respectively. The dimensions are shown in both figures. The finite semi cylindrical curved FSSs are 200mm in diameter and 300mm in length in all designs. The Koch snowflake based FSSs are shown from fig2 to fig4 according to the iterations.

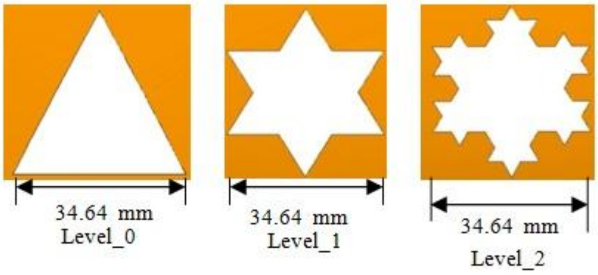

Figure 1: Iterations of Koch snowflake fractal element.

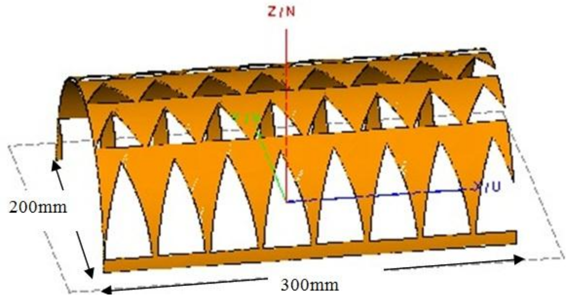

Figure 2: Curved Koch snowflake fractal FSS (Level_0)

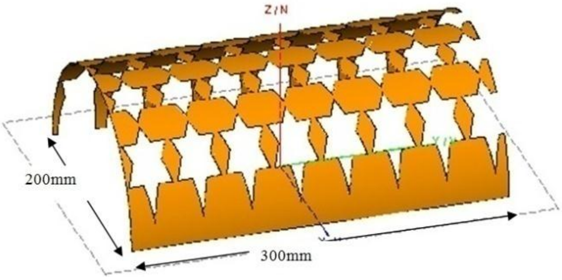

Figure 3: Curved Koch snowflake fractal FSS (Level_1)

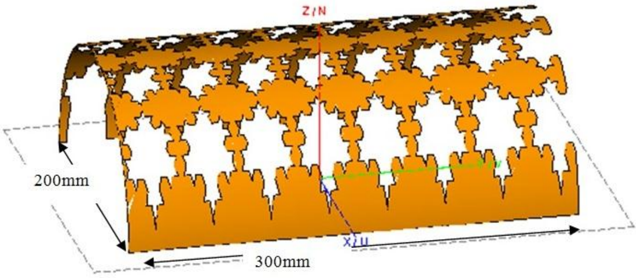

Figure 4: Curved Koch snowflake fractal FSS (Level_2)

The length of unit aperture element of Koch snowflake and Vicsek fractals are 34.64mm and 27mm respectively .Also the curved Vicsek fractal FSSs are demonstrated from fig6 to fig 8 according to the iteration level. The periodic distance between the fractal element in both types of fractal FSS is 4mm.Thin aluminum foil is taken as metal sheet and air is considered as dielectric substrate with dielectric constant 1.The fractal element is etched out from metallic sheet to form curved FSSs. The designs are done by Auto CAD and FEKO. All the designed curved FSS are simulated by FEKO simulator to analyze their characteristics.

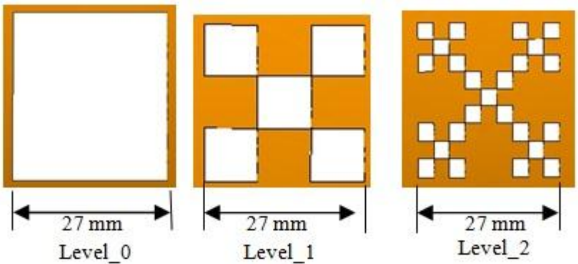

Figure 5: Iterations of Vicsek fractal element.

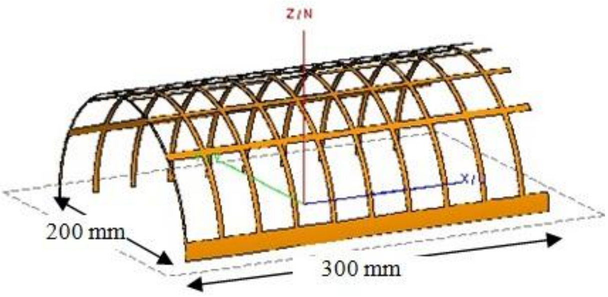

Figure 6: Curved Vicsek fractal FSS (Level_0)

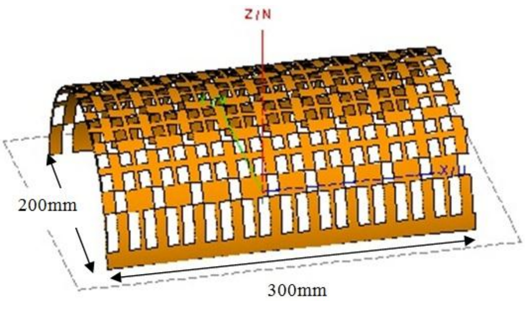

Figure 7: Curved Vicsek fractal FSS (Level_1)

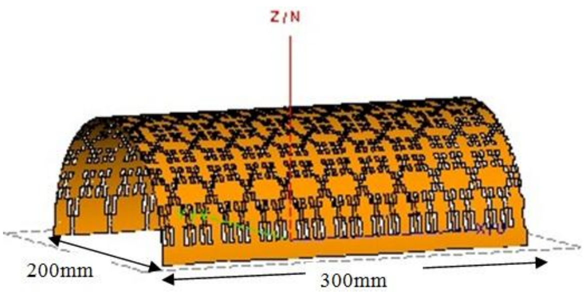

Figure 8: Curved Vicsek fractal FSS (Level_2)

RESULTS

The transmission characteristics of the two fractal curved semi cylindrical FSSs are shown in fig 9 and fig 10 with iteration level 2. All fractal FSS are analyzed up to level 2 for avoiding the complexity of design. From fig 9 it has been observed that multiband in transmission characteristics has been obtained for level _0. In level_1 of Koch snow flake curved FSS 9.87GHz bandwidth has been achieved. In Koch snowflake fractal curved FSS , the characteristics depends on the metal element of the designs. Minimum metal portion presents in the level_2 design. The metal portion is in descending nature in level wise. No of bands has been decreased by increasing the iteration no. of the Koch snowflake fractal element. The frequency response of Vicsek fractal FSS is complementary in nature with respect to Koch snowflake fractal curved FSS due to their metal portion in the design. The characteristics is shown in fig10. In fig10, it has been noticed that the multiband in level 2 of fractal, dual band in level 1and single broad band for level 0. In level_0 of Vicsek fractal aperture type curved FSS, 19.45GHz broad band has been achieved. So here number of bands can be increased by increasing the iteration numbers. From fig 5, it has been observed that with the increase of iteration numbers of fractal aperture element the metal portion is reduced. But in fig 1, inverse nature is obtained. The transmission characteristics of fractal curved FSS mainly depends on the fractal element not on the iteration numbers.

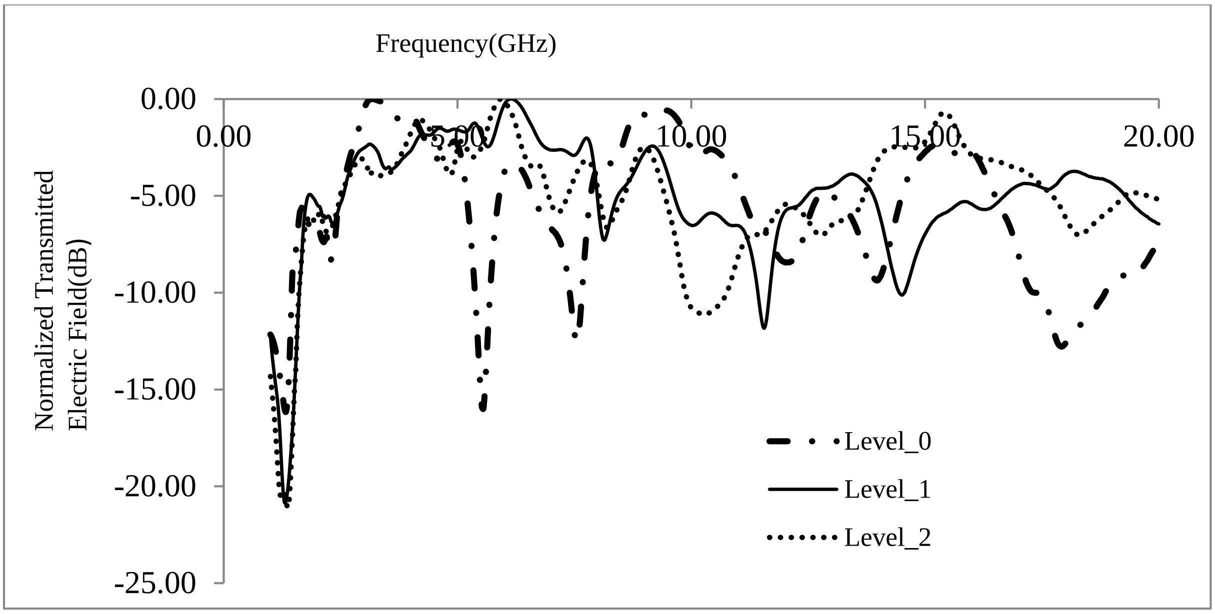

Figure 9: Transmission Characteristics of Koch snowflake curved aperture type curved FSS

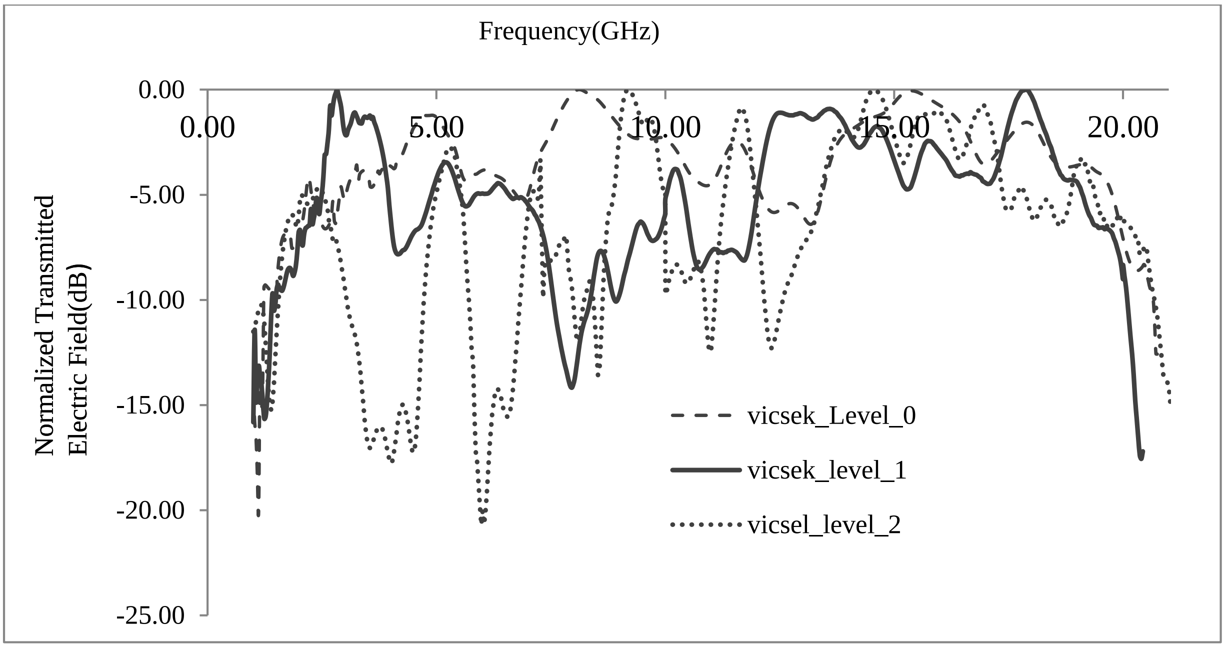

Figure 10: Transmission Characteristics of Vicsek fractal curved aperture type curved FSS

CONCLUSIONS

Fractal curved FSS may be used in multi frequency operation as well as wide band applications. It is a very new approach to design curved fractal FSS. The Vicsek fractal curved FSS (level_2_) operates at 2.54 GHz and 5.32 GHz. It can be used in Bluetooth, Wi-Fi ,WLAN application purposes. It can be used in satellite communications due to its broad bandwidth (19.45GHz). So it can be concluded that number of band is directly proportional to the metallic element. In Koch snowflake, metal in the curved FSS is minimum at maximum iteration. But, Vicsek fractal follows the opposite nature. So there is an inverse relationship in transmission characteristics between the two different fractal element based curved FSS. A fruitful frequency response can be achieved by changing the iteration level of a fractal element in curved fractal FSS. Broadband or multiband depends on the fractal element not on the iteration level of the fractal.

REFERENCES:

[1] Ben A. Munk, 2000 , "Frequency Selective Surfaces, Design and Theory", John Wiley & Sons, Inc. New York,

[2] N. Begam ,P. Samaddar, S. Saha, S.Sarkar, D. C (Sarkar), P. P. Sarkar , Oct 2017 ,"Design of curved frequency selective surface with high roll off", 59 (10), ,pp 2660–2664.

[3] J. Romeu, Y. Rahmat-Samii, JULY 2000, "Fractal FSS:A Novel Dual-Band Frequency Selective Surface ", IEEE Trans. on Antennas And Propagation, 48, (7).

[4] Robson H. C. Maniçoba, A. Luiz ,P. S. Campos, T. de Lima Silva and A. Gomes d'Assunção, 2011, "Experimental Investigation of FSS Cascading with Fractal Elements" IEEE conference.

[5] R. Panwar ,S. Puthucheri, V. Agarwala, and D. Singh, AUGUST 2015, ″ Fractal Frequency-Selective Surface Embedded Thin Broadband Microwave Absorber Coatings Using Heterogeneous Composites", IEEE Trans. On Microwave Theory And Techniques, 63 (8), pp 2438-2448.

[6] Ravi Panwar, Smitha Puthucheri1, Arunima Singh, Dharmendra Singh, Vijaya Agarwala, 2015,"Critical Analysis of Fractal FSS with Heterogeneous Composite to Enhance Microwave Absorption for Stealth Application", IEEE International Microwave and RF Conference (IMaRC), pp 416-418.

[7] T.K. Wu, 2016, "Improved THz/Infrared Frequency Selective Surface with Minkowski Fractal Elements", 978-1-5090-1259-6/16/$31.00 ©2016 IEEE.

[8] A. Singh', R. Panwar, S. Puthucheri, D.Singh, V. Agarwalal, Feb 2015, "Parametric Analysis of Frequency Selective Surfaces Over Radar Absorbing Nanocrystalline Structures", National Conference on Recent Advances in Electronics & Computer Engineering, NIT Roorkee, India, pp 75-79.

[9] R. Panwar, S. Puthucheri, V. Agarwala , D. Singh, Feb 2015, "Fractal Frequency Selective Surface Embedded Broadband Microwave Absorber using Disassembled Waste Printed Circuit Boards", National Conference on Recent Advances in Electronics & Computer EngineeringliT Roorkee, India. pp 116-119.

[10] M. Basravi, M. Maddahali, Z. H. Firouzeh, and A. Ramezani, 2016," Design of a Novel Ultra Broadband Single-Layer Absorber Using Double Fractal Square Loops", 24th Iranian Conference on Electrical Engineering (ICEE).

[11] Y. Mannaa, R.W. Aldhaheri, 2016, "New Dual-Band Frequency Selective Surface for GSM Shielding in Secure-Electromagnatic Buildings Using Square Loop Fractal Configurations ", IEEE Conference.

[12] Z. Zhao, H.Shi, J. Guo, W.Li, and A. Zhang, 2017 "Stop band Frequency Selective Surface With Ultra-Large Angle of Incidence, IEEE Antennas And Wireless Propagation Letters, 16, pp 553-556.